

ZOOM LENS SYSTEM FOR COVERING SUPERWIDE-ANGLE AREA

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 The present invention relates to a zoom lens system of two lens groups, which is suitable for a taking lens of a camera to cover a superwide-angle area.

2. Description of the Related Art

A zoom lens to be used for a compact camera has a
10 variable-power ratio of about two times and is different from a zoom lens to be used for a single-lens reflex camera. As to the zoom lens of the compact camera, since a long back focus is not necessary, the lens structure thereof is a two-group structure comprising a positive first lens group and a negative second lens group, which are arranged
15 in order from an object side. In virtue of this structure, it is possible to shorten the total length and the back focus. Meanwhile, it is known that a wide angle of view is obtained without enlarging a lens diameter when an
20 object-side surface of a first lens is a concave surface. By adopting this kind of the lens structure, both of downsizing and the wide angle of view are realized (see the following patent documents, for instance).

[Patent Document 1]

25 Japanese Patent Laid-Open Publication No.6-82696

[Patent Document 2]

Japanese Patent Laid-Open Publication No.2001-343586

[Patent Document 3]

Japanese Patent Laid-Open Publication No.7-146439

(Japanese Patent Publication No.3264067)

With respect to the conventional lenses, however,
5 the overall angle of view at a wide-angle side is about
75°. When applying a wider-angle lens, it is impossible
to sufficiently correct various aberrations of marginal
lumination, distortion and so forth.

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SUMMARY OF THE INVENTION

In view of the foregoing, it is a primary object of
the present invention to provide a zoom lens of small
size in which an overall angle of view is 80° or more.

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It is a second object of the present invention to
provide a zoom lens of small size in which various
aberrations are sufficiently corrected.

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In order to achieve the above and other objects, the
zoom lens according to the present invention comprises
a first lens group having positive refracting power and
a second lens group having negative refracting power,
which are arranged in order from an object side. The first
lens group and the second lens group are moved to reduce
an interval between them so that magnification is changed
from a wide-angle end to a telephoto end. The first lens
group includes first to fourth lenses in order from the
object side. The first lens has negative refracting power
and a concave surface thereof faces the object side. The

second lens has positive refracting power. The third lens has negative refracting power. The fourth lens has positive refracting power. The zoom lens of the present invention satisfies the following conditions.

- 5 (1) $-2.7 < f_s/f_1 < -1.7$
 (2) $-1.1 < f_1/f_2 < -0.9$

f_s : Focal Length of Overall System at Wide-Angle End

f_1 : Focal Length of the First Lens

f_2 : Focal Length of the Second Lens

10 The zoom lens is preferable to further satisfy the following condition.

- (3) $1.0 < r_1/f_1 < 3.0$

r_1 : Radius of Curvature at Object Side of the First Lens

Moreover, both faces of the second lens are
15 preferable to be a convex surface and at least one of
the faces is preferable to be a glass lens of an asphere.

Furthermore, the third lens and the fourth lens are
preferable to be a cemented lens.

According to the present invention, it is possible
20 to obtain the zoom lens, which is compact and has the
angle of view of 80° or more at the wide-angle end.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and advantages of the present
25 invention will become apparent from the following
detailed description of the preferred embodiments of the
invention when read in conjunction with the accompanying

drawings, in which:

Figs. 1A and 1B are sectional views showing a zoom lens according to the present invention;

Figs. 2A to 2C are aberration charts of Example 1;

5 Figs. 3A to 3C are aberration charts of Example 2;

Figs. 4A to 4C are aberration charts of Example 3;

Figs. 5A to 5C are aberration charts of Example 4;

Figs. 6A to 6C are aberration charts of Example 5;

and

10 Figs. 7A to 7C are aberration charts of Example 6.

DETAILED DESCRIPTION OF THE

PREFERRED EMBODIMENT(S)

A zoom lens according to the present invention is
15 of a telephoto type comprising a positive first lens group
and a negative second lens group, in order to shorten
a total length extending from a lens surface, which is
nearest to a subject, to a focal plane. When zooming is
performed from a wide-angle end toward a telephoto end,
20 the first and second lens groups are moved to an object
side to reduce an interval thereof.

In the present invention, the first lens group I is
constituted of a first lens G1 having negative refracting
power, a second lens G2 having positive refracting power
25 and an asphere, a third lens G3 having negative refracting
power, and a fourth lens G4 having positive refracting
power. An effective diameter of the first lens is likely

to be large as an angle of view at the wide-angle end becomes wider. Notwithstanding, by making an object side of the first lens a concave surface, it is possible to widen the angle of view in a state that the lens diameter 5 is kept in a small size. However, by comparison with another case in that a convex surface is directed to the object side, an angle of refraction becomes large as the axial ambient light nears to a peripheral portion of a picture. Accordingly, coma and astigmatism increase. 10 In view of this, the first lens is set so as to satisfy the following condition (1). By doing so, it is possible to strike a balance between utility and performance.

$$(1) -2.7 < fs/f1 < -1.7$$

The condition (1) concerns a power of the first lens. 15 Upon exceeding the upper limit of the condition (1), negative curvature of field and positive distortion increase due to lack of lens power. As to the main light of the wide view angle becoming incident on a stop surface, an angle thereof is large relative to an optical axis. 20 Thus, vignetting is caused due to thickness of a stop when an aperture is small. Meanwhile, upon falling below the lower limit, it becomes difficult to correct aberration with another lens due to an excess of lens power. Moreover, it is likely to be influenced by 25 fabrication errors. Incidentally, fs denotes a focal length of the overall system at the wide-angle end, and $f1$ denotes a focal length of the first lens.

Further, the second lens is set so as to satisfy the following condition (2). By doing so, it is possible to properly correct various aberrations.

$$(2) -1.1 < f_1/f_2 < -0.9$$

5 The condition (2) concerns power balance of the first lens and the second lens. In the zoom lens according to the present invention, the power of the first lens is set so as to be high for the purpose of obtaining the wide angle of view. In order to correct the 10 aberration generated in the first lens, it is necessary to satisfy the condition (2). Upon exceeding the upper limit of the condition (2), the power of the second lens becomes insufficient in comparison with the first lens. Thus, it is difficult 15 to correct the aberration generated in the first lens. Meanwhile, upon falling below the lower limit, the power of the second lens becomes too great so that it is difficult to strike a balance between aberrations of the third lens and the fourth lens.

20 The following condition (3) concerns a radius of curvature regarding the object side of the first lens. This radius of curvature is denoted by r_1 .

$$(3) 1.0 < r_1/f_1 < 3.0$$

Upon exceeding the upper limit of the condition (3), 25 the radius of curvature becomes large. In other words, the lens diameter becomes large so that it is difficult to secure marginal illumination at the

wide-angle end. Meanwhile, upon exceeding the lower limit, the radius of curvature becomes too small. Due to this, coma and astigmatism increase so that it becomes difficult to correct them with the second lens.

- 5 With respect to luminous flux of the wide view angle, an amount of light rays passing a side, that is separated from an optical axis on an entrance pupil, becomes too great on a stop surface, and luminous flux surface density lowers on the stop surface. Thus, the marginal lumination
10 lowers when the aperture is small.

The second lens has an asphere in order to mainly correct spherical aberration and coma. However, since strong power is necessary, the radius of curvature becomes too small in a case of a plastic asphere. As a result,
15 various aberrations and sensitivity for the fabrication error increase. In view of this, it is desirable to use a glass asphere having a high refractive index, preferably having a refractive index of 1.6 or more. In the case of the plastic lens, it is difficult to prevent movement
20 of focal point caused by changes of temperature and humidity.

Further, it is desirable to satisfy the following condition (4).

$$(4) N_1 > N_2$$

- 25 In this condition, N_1 and N_2 denote refractive indexes of the first and second lenses respectively. Upon departing from the scope of the condition (4), Petzval's

sum becomes too small. When the astigmatism is small, curvature of field is excessively corrected.

The third lens and the fourth lens are desirable to be a cemented lens. In virtue of the cemented lens, it 5 is possible to correct chromatic aberration, spherical aberration and coma without strictly restraining the fabrication error.

Furthermore, it is preferable that the third lens and the fourth lens satisfy the following conditions (5) 10 and (6).

$$(5) \nu_3 < \nu_4$$

$$(6) N_3 > N_4$$

In these conditions, ν_3 and ν_4 are Abbe numbers of the third and fourth lenses respectively, and N_3 and N_4 are 15 refractive indexes of the third and fourth lenses respectively. Upon departing from the scope of the condition (5), it is difficult to correct the axial chromatic aberration. Upon departing from the scope of the condition (6), it is difficult to correct the spherical 20 aberration.

The second lens group comprises a positive fifth lens G5 and a negative sixth lens G6, which are arranged in order from the object side. When the view angle of the wide-angle end is widened, the negative lens nearest to 25 an image side is likely to have a large effective diameter, similarly to the first lens. In view of this, a positive aspherical lens is disposed at an object side of the

negative lens so as to strengthen the positive power at the outside of the axis. By reducing an incidence amount of the negative lens, the marginal illumination may be obtained without enlarging the lens diameter. It is
5 desirable that Abbe number of the fifth lens is 40 or more. In a case that this Abbe number is less than 40, it is difficult to correct transverse chromatic aberration of the wide-angle side. Refracting power of this lens is small so that it is possible to use a plastic.

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EXAMPLE 1

Table 1 shows values of R (mm), D (mm), N and ν , wherein R denotes a radius of curvature of each lens surface, D denotes central thickness of each lens and airspace between the respective lenses, N denotes a
15 refractive index at the d-line of each lens, and ν denotes the Abbe number. Incidentally, in the table, each number written in a column of the surface (SUR.) represents the order succeeding from the object side. With respect to "*", it is described later. Meanwhile, Figs. 1A and 1B
20 show sectional views of the lenses and Figs. 2A to 2C show various aberrations of a wide-angle end, a middle focal length, and a telephoto end. By the way, in the attached drawings, d and g denote the spherical aberrations at the d-line and the g-line respectively.
25 Further, S denotes a sagittal image surface, and M denotes a meridional image surface.

[TABLE 1]

	SUR.	R	D	N	ν
	1	-27.598	0.90	1.72825	28.3
	2	12.388	0.15		
*	3	10.683	3.00	1.68410	31.3
*	4	-29.152	3.30		
	5	-166.352	1.00	1.84666	23.8
	6	16.913	3.60	1.72342	38.0
	7	-11.383	D7		
*	8	-39.993	3.10	1.52470	56.2
*	9	-24.276	4.15		
	10	-8.940	1.30	1.80420	46.5
	11	-41.979			

D7 means a value varying in accordance with zooming. Table 2 shows D7, focal length f, F-number F, back focus FB and half angle of view ω , wherein W denotes the wide-angle end, M denotes the middle focal length, and T denotes the telephoto end.

[TABLE 2]

	W	M	T
D7	6.57	3.28	0.99
f	24.7	34.8	48.5
F	4.5	5.0	5.75
FB	7.05	17.05	30.65
ω	41.2	31.87	24.3

In Table 1, "*" written at the left side of the

surface number means that the surface concerned is the aspheric surface. The shape thereof is expressed by the following equation in rectangular coordinates, the original of which is the vertex of the surface and an X-axis of which is in an optical-axis direction. In the following Table, "E+i" represents " $\times 10^i$ " and "E-i" represents " $\times 10^{-i}$ ".

[EQUATION 1]

$$X = \frac{\frac{Y^2}{R}}{1 + \sqrt{1 - (1+K) \frac{Y^2}{R^2}}} + AY^4 + BY^6 + CY^8 + DY^{10} + EY^{12}$$

Y: Height from the Optical Axis

R: Radius of Curvature of the Vertex

K: Conic Constant

A, B, C, D and E: Aspheric Coefficients

[TABLE 3]

SUR.	K	A	B	C	D	E
3	9.47240E-02	-1.18940E-04	1.97590E-06	-7.89970E-08	7.09390E-09	-1.39760E-10
4	-1.51134E+00	1.74700E-04	1.16430E-06	9.95650E-08	3.64390E-09	-8.20770E-11
8	1.31540E+00	3.38660E-05	2.14130E-06	-3.78340E-08	3.48640E-10	-1.68970E-12
9	-1.19213E-01	-8.09040E-05	1.80570E-06	-6.53940E-08	9.32790E-10	-7.88280E-12

A position of the stop is optional. However, it is desirable to dispose the stop between the fourth surface and the fifth surface in order to secure the marginal lumination at the time of small aperture.

As shown at the right side of Fig. 2A, the aberrations except the marginal lumination are

satisfactorily corrected even if the diameter is further enlarged at the wide-angle end. Thus, although the F-number of the wide-angle end is 4.5 in this example, the F-number may be about 2.95 in
5 night-scene photographing or the like, wherein the marginal illumination is not cared. Especially, the astigmatism and the coma are satisfactorily corrected at a periphery of a picture so that it is possible to depict a point light source having the bright
10 background, without deforming a shape thereof.

When a person is photographed with the background of night scenes, flashlight is emitted at a position of F4.5 on the way to opening a shutter. After that, the shutter is opened until F2.95. In virtue of this,
15 the background is photographed in the brightness of F2.95, and the flashlight is emitted at F4.5 wherein the marginal illumination is sufficient. Thus, it is possible to obtain a depiction in which both of the subject and the background are satisfactory.

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EXAMPLE 2

A zoom lens of Example 2 has a similar structure with that of Example 1. Table 4 shows values of the respective lens surfaces of Example 2. Table 5 shows data of each zooming step, and Table 6 shows aspheric
25 coefficients. Meanwhile, Fig. 1 shows sectional views of the lenses, and Fig. 3 shows various aberrations of the respective zooming steps.

[TABLE 4]

	SUR.	R	D	N	ν
	1	-27.804	0.90	1.74400	44.9
	2	12.361	0.15		
*	3	10.724	3.00	1.69350	53.2
*	4	-28.950	3.30		
	5	-169.616	1.00	1.84666	23.8
	6	17.154	3.60	1.72342	38.0
	7	-11.383	D7		
*	8	-40.544	3.10	1.52470	56.2
*	9	-23.972	4.15		
	10	-8.928	1.30	1.80420	46.5
	11	-41.797			

[TABLE 5]

	W	M	T
D7	6.60	3.28	0.96
f	24.7	34.8	48.5
F	5.6	6.3	7.8
FB	7.13	17.21	30.93
ω	41.2	31.87	24.3

[TABLE 6]

SUR.	K	A	B	C	D	E
3	3.90660E-02	-9.56460E-05	1.55090E-06	-1.55940E-07	7.36440E-09	-6.14480E-11
4	1.72160E-01	1.84380E-04	9.48790E-07	8.72500E-08	2.04810E-09	-1.79340E-10
8	1.31540E+00	3.37420E-05	2.06780E-06	-2.43510E-08	5.83590E-10	-7.26270E-12
9	-4.46772E-01	-7.23550E-05	1.06010E-06	-3.85470E-08	8.42890E-10	-8.76270E-12

EXAMPLE 3

A zoom lens of Example 3 also has a similar structure with that of Example 1. Table 7 shows values of the respective lens surfaces of Example 3. Table 8 shows data of each zooming step, and Table 9 shows aspheric coefficients. Meanwhile, Fig. 1 shows sectional views of the lenses and Fig. 4 shows various aberrations of the respective zooming steps.

[TABLE 7]

	SUR.	R	D	N	v
	1	-31.119	0.90	1.76182	26.5
	2	15.269	0.15		
*	3	12.051	3.00	1.68410	31.3
*	4	-31.922	3.30		
	5	-133.555	1.00	1.84666	23.8
	6	16.670	3.60	1.72342	38.0
	7	-11.346	D7		
*	8	-31.000	3.10	1.52470	56.2
*	9	-21.108	4.15		
	10	-8.709	1.30	1.80420	46.5
	11	-39.469			

[TABLE 8]

	W	M	T
D7	7.16	3.93	1.69
f	24.7	34.8	48.5
F	5.6	6.3	7.8
FB	6.33	15.88	28.90
ω	41.2	31.87	24.3

[TABLE 9]

SUR.	K	A	B	C	D	E
3	-3.18760E-02	-9.86090E-05	2.70010E-06	-6.12650E-08	1.65550E-09	-2.94320E-11
4	5.20132E-01	1.76940E-04	2.81580E-06	4.32210E-08	9.57040E-09	-7.06740E-10
8	1.31540E+00	3.93500E-05	2.01920E-06	-4.60440E-08	4.42810E-10	-2.36730E-13
9	-4.09474E-01	-9.96530E-05	1.96160E-06	-7.48700E-08	8.76600E-10	-6.35980E-12

EXAMPLE 4

A zoom lens of Example 4 also has a similar structure with that of Example 1. Table 10 shows values of the respective lens surfaces of Example 4. Table 11 shows data of each zooming step, and Table 12 shows aspheric coefficients. Meanwhile, Fig. 1 shows sectional views of the lenses and Fig. 5 shows various aberrations of the respective zooming steps.

[TABLE 10]

	SUR.	R	D	N	v
	1	-21.283	0.90	1.72825	28.3
	2	11.559	0.15		
*	3	10.403	3.00	1.68410	31.3
*	4	-21.877	3.30		
	5	-150.218	1.00	1.84666	23.8
	6	15.344	3.60	1.72342	38.0
	7	-11.345	D7		
*	8	-52.443	3.10	1.52470	56.2
*	9	-22.217	4.15		
	10	-8.9133	1.30	1.80420	46.5
	11	-57.712			

[TABLE 11]

	W	M	T
D7	6.57	3.18	0.83
f	24.7	34.8	48.5
F	5.6	6.0	6.8
FB	7.57	17.70	31.51
ω	41.2	31.87	24.3

[TABLE 12]

SUR.	K	A	B	C	D	E
3	1.50660E-02	-1.22000E-04	1.91270E-06	4.06440E-08	1.19970E-08	-2.82760E-10
4	-1.48750E+00	1.62000E-04	1.06460E-06	1.91470E-07	1.03840E-08	-2.07420E-10
8	1.31540E+00	1.38570E-05	2.18470E-06	-3.85960E-08	2.96010E-10	-1.07690E-12
9	-2.37742E-01	-1.14000E-04	1.84820E-06	-6.70900E-08	9.11980E-10	-7.86600E-12

EXAMPLE 5

A zoom lens of Example 5 also has a similar structure with that of Example 1. Table 13 shows values of the respective lens surfaces of Example 5. Table 14 shows data of each zooming step, and Table 15 shows aspheric coefficients. Meanwhile, Fig. 1 shows sectional views of the lenses and Fig. 6 shows various aberrations of the respective zooming steps.

[TABLE 13]

	SUR.	R	D	N	v
	1	-20.500	0.90	1.72825	28.3
	2	11.881	0.15		
*	3	10.542	3.00	1.68893	31.1
*	4	-18.905	3.30		
	5	-109.929	1.00	1.84666	23.8
	6	16.542	3.60	1.72342	38.0
	7	-12.047	D7		
*	8	-41.450	3.10	1.52470	56.2
*	9	-19.684	4.15		
	10	-8.659	1.30	1.7725	49.6
	11	-55.009			

[TABLE 14]

	W	M	T
D7	6.82	3.25	0.77
f	24.7	34.8	48.5
F	5.6	6.0	7.8
FB	7.06	17.20	30.99
ω	41.2	31.87	24.3

[TABLE 15]

SUR.	K	A	B	C	D	E
3	-4.77818E-01	-1.33103E-04	9.30710E-06	-9.15470E-07	3.92290E-08	-4.86660E-10
4	5.08748E-01	1.25269E-04	-6.30970E-07	5.28180E-07	-4.21550E-08	1.16790E-09
8	1.31540E+00	3.37730E-05	9.49270E-07	-2.39840E-08	5.51710E-10	-3.75680E-12
9	5.00299E-01	-8.10850E-05	6.35840E-07	-4.65700E-08	7.52740E-10	-6.55580E-12

EXAMPLE 6

A zoom lens of Example 6 also has a similar structure with that of Example 1. Table 16 shows values of the respective lens surfaces of Example 6. Table 17 shows data of each zooming step, and Table 18 shows aspheric coefficients. Meanwhile, Fig. 1 shows sectional views of the lenses and Fig. 7 shows various aberrations of the respective zooming steps.

【TABLE 16】

SUR.	R	D	N	ν
1	-15.000	0.90	1.72825	28.3
2	14.617	0.15		
*	3	12.104	3.00	1.68893
*	4	-15.304	3.30	
	5	-187.376	1.00	1.84666
	6	17.478	3.60	1.72342
	7	-13.473	D7	
*	8	-62.488	3.10	1.52470
*	9	-22.448	4.15	
	10	-9.827	1.30	1.7725
	11	-121.751		49.6

【TABLE 17】

	W	M	T
D7	7.42	3.45	0.69
f	24.7	34.8	48.5
F	5.6	6.0	7.8
FB	6.97	17.44	31.69
ω	41.2	31.87	24.3

【TABLE 18】

SUR.	K	A	B	C	D	E
4	2.64070E-02	-2.08580E-04	9.79990E-06	-1.13940E-06	5.13620E-08	-8.28130E-10
5	3.26841E-01	9.92640E-05	-3.88590E-06	6.86810E-07	-5.31000E-08	1.34420E-09
8	1.31540E+00	2.98280E-05	-3.23970E-07	-4.73040E-09	5.16190E-10	-4.31130E-12
9	8.87740E-01	-5.45060E-05	1.62210E-07	-3.00280E-08	5.51890E-10	-2.93500E-12

Table 19 shows values of the conditions (1) to (3) of the respective Examples.

[TABLE 19]

	EX.1	EX.2	EX.3	EX.4	EX.5	EX.6
(1) f_s/f_1	-2.13	-2.17	-1.85	-2.43	-2.42	-2.46
(2) f_1/f_2	-1.00	-0.98	-1.01	-0.95	-0.99	-0.97
(3) r_1/f_1	2.37	2.44	2.33	2.09	2.01	1.49

Incidentally, the compact wide-angle zoom lens of the present invention is not exclusive to the above embodiments. It is possible to adequately select the shapes, the materials, the aspheric coefficients and so forth of the respective lenses.

Although the present invention has been fully described by way of the preferred embodiments thereof with reference to the accompanying drawings, various changes and modifications will be apparent to those having skill in this field. Therefore, unless otherwise these changes and modifications depart from the scope of the present invention, they should be construed as included therein.